STUDIES IN CHEMICAL MILLING OF MAGNESIUM ALLOYS

A. Narayana, Krishnadas Nair, B. Chatterji and S. S. Srinivasan

Central Laboratory, Foundry & Forge Division, Hindustan Aeronautics Limited, Bangalore-560 017

(Received Feb. 1978, accepted May, 1978)

Based on preliminary experiments, dilute solutions of Nitric acid was chosen as chemical for milling of magnesium alloys. The milling rate and surface finish for pure magnesium and four magnesium alloys were studied as a function of concentration of the chemical. Electrode potential of the test materials was assessed as a function of concentration of the chemical and its effect on milling rate was studied.

It is well known that chemical milling can be successfully used for contour and taper etching of metals and alloys. The process consists of dissolution of metal by the use of chemical, the controlling factors being electrode potential of the metal, strength of chemical solution, temperature, duration of etching etc. There are several advantages of chemical milling over mechanical milling. Parts can be milled on both surfaces simultaneously. Production rates and the maximum size of parts that can be processed are governed by the capacity of the etchant tank and warpage is minimised. In the case of large and intricate castings the cutting tool in mechanical milling may not be able to reach the intricate points, whereas in chemical milling the etchant will reach any intricate point.

There is very little published literature on chemical milling of magnesium alloys. Available literature [1,2] suggests the use of various chemicals like sulphuric acid hydrochloric acid and nitric acid. However, a proven process is not available in text books or in the form of published technical Paper. A systematic study of chemical milling of a number of magnesium alloys was therefore undertaken in the Central Laboratory of Hindustan Aeronautics Ltd., Bangalore and this Paper is based on the results of this investigation.

EXPERIMENTAL

Pure magnesium and four types of magnesium alloys of nominal composition indicated in Table 1. were selected for this investigation.

TABLE 1. Magnesium Alloy Compositions (RE Total Rare Earths)

	Nominal composition (weight percent)					
	Zn	Zr	Mn	Al	Fe	RE
Alloy-1	3.0	0.68	0.08	—	—	2.7
Alloy-2	5.0	0.88	0.06	—	—	—
Alloy-3	5 0	0.90	0.06	—	—	1.5
Alloy-4	0 8	—	0.27	8.0	—	—
Pure Mg.	—	—	0.04	Traces	Traces	—

Preliminary experiments were carried out using dilute solutions (5, 10 and 15 percent) of Sulphuric acid, Hydrochloric acid and Nitric acid to study their effect on surface finish so as to select a suitable chemical for detailed investigation. Small round specimens of the alloys were etched in these solutions for a period of 5 minutes. It was observed that the reaction was very fast in the sulphuric acid resulting in sudden rise in temperature, surface finish was also rough In the case of hydrochloric acid reaction was fast and the etched surface had poor finish and was dull in appearance. Also there was smut formation on the surface in both the above two cases. In the case of Nitric acid the reaction was comparatively slower and there was only a slight smut formation on the surface which could be easily washed out in cold running water. The surface finish was comparatively much better and the surface had a bright appearance. Fig. 1 illustrates the appearance of the surface of Alloy-4 after milling for five minutes in different solutions of 15% concentration.



A B C

Fig. 1 Comparison of surface finish after chemical milling

A) 15% Nitric Acid; B) 15% Sulphuric Acid;
C) 15% Hydrochloric Acid.

Based on the preliminary experiments, nitric acid was selected as a suitable chemical for further detailed investigation. Nitric acid solutions with varying concentrations prepared and the milling rate (dissolution rate) of various alloys with time was assessed in these solutions.

Specimens 5 cms. long and 10 mm. dia. were fabricated in the respective alloys were used in the current investigation. Milling rate was studied by suspending the specimen in a beaker containing the solution of the particular strength and ensuring that the half of the length of the specimens were immersed. At set intervals of time the specimen was withdrawn, washed and dried and the reduced diameter measured using a micrometre. The reduction in diameter is halfed to obtain the equivalent milling rate per surface. Electrode potential was measured for all the alloys as a function of the concentration of solutions with reference to a standard Calomel electrode. The test solution was kept in a beaker in which the test sample together with the calomel electrode was immersed and were connected externally to a potentiometer. The stabilised potential was recorded and in all the cases stability reached in about one minute. However, the measuring was continued upto 3 minutes ensuring that there is no change in the potential.

The surface finish of the chemically milled specimens were examined visually and selected specimens were quantitatively assessed for surface finish by using a talysurf instrument. Further chemical milling as well as contour milling of some components in these alloys were carried out with areas not to be milled being masked by strippable lacquer. The results of this milling trials were compared with what was predicted from the preliminary experiments.

RESULTS AND DISCUSSION

Fig 2 shows electrode potential Vs concentration of nitric acid for pure magnesium as well as alloys. It is seen that alloying in general reduced the electrode potential of pure magnesium. The variation in electrode potential with respect to concentration is more or less same with that of pure magnesium for alloys 1, 2 and 3 as seen from the slope of the graphs in Fig. 2. However, for alloy No. 4, the electrode potential increases at a much faster rate than for pure magnesium and other alloys. This difference may be due to presence of aluminium in alloy No. 4. In case of magnesium alloys containing zinc and rare earths, although there is marked decrease in the electrode potential as compared to pure magnesium the variation of electrode potential with concentration was more or less the same as that of pure magnesium.

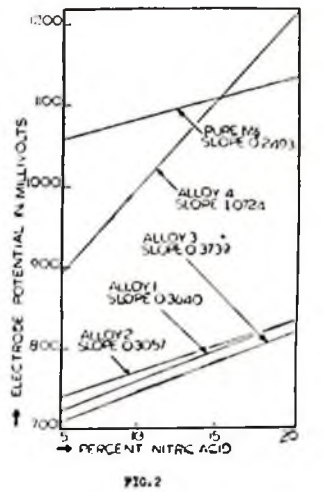


Fig. 2 Effects of concentration of Nitric Acid on electrode potential

Fig. 3 shows rate of metal removal (milling rate) as a function of concentration of the chemical. The milling rate is very slow in all the cases upto a concentration of about 10 percent beyond which the rate increased steeply. However, as the rate of dissolution increased this was followed by an increase in temperature : The temperature rise was measured by using a thermometer. Upto about 8 percent concentration, the rise in temperature was marginal. However, there was a steep rise in temperature as the concentration increased from 10 to 20 percent. Beyond 15 percent the temperature increased upto 90°c. Between 15 to 20 percent concentration and at the high temperature ie. 90°C. liberation of nitrogen peroxide was noticed. With proper cooling of the solution to maintain a temperature of 40-50°C, the high milling rates achievable at these higher concentrations could be utilised. At a concentration of about 14 to 16 percent, a milling rate of 150 to 200 microns per minute per surface can be achieved for all the alloys considered. Surface finish measurements of the specimens showed that the finish did not vary much with the time in solutions of different concentrations and the finish was about one micron or better.

Fig. 4 shows milling rate Vs. electrode potential for pure magnesium and alloys. It was interesting to note that although difference in electrode potential was significant between pure magnesium and the alloys

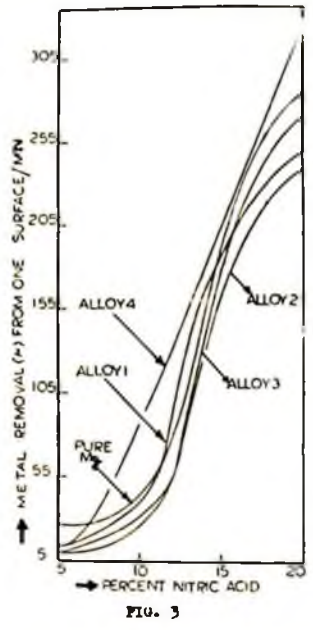


Fig. 3 Effect of concentration of Nitric Acid on metal removal

1, 2 and 3, such marked difference was not observed in the milling rate for these alloys ie. to say that alloys 1, 2 and 3 although at a much lower electrode potential at any given concentration dissolved more or less at the same rate as that of pure magnesium. Therefore it is not possible to have a single relationship between electrode potential and dissolution rate for all the alloys.

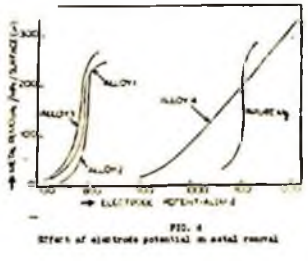


Fig. 4 Effect of electrode potential on metal removal

Chemical milling of medium size components in magnesium alloys for specific periods in 15% solution gave satisfactory results. The milling rate and finish were comparable with those obtained during experiments. using turned specimens. During the trial chemical milling of cast components, it was observed that surface defects such as cracks, shrinkage and porosity were revealed easily after a slight initial chemical milling. This was further investigated using castings with non defects and in all cases the defects were revealed after chemical milling for a period of about one minute. This will be particularly useful for sand castings which have fairly rough surface finish which normally obscure defects even during dye penetrant inspection. Sand castings with rough finish are generally sand blasted to reduce this problem. Chemical milling after sand blasting will considerably aid the detection of surface defects and the process can be used for this purpose.

CONCLUSIONS

Chemical milling of the magnesium alloys can be carried out successfully using nitric acid solutions. The solution of 14–16% concentration with cooling to maintain temperature below 50°C. will give best results. Uniform rate (150–200 microns per minute) of milling can be achieved at this concentration and the milled surface has a good finish of the order of 1 micron or better.

Alloying of magnesium with aluminium and zinc reduces the electrode potential of magnesium considerably. However, the rate of increase in electrode potnetial with increase in concentration was similar for both pure magnesium and its alloys containing zinc with the exception of aluminium bearing alloy for which the increase was steeper. Although in all cases the milling rate increased was steeper, in electrode potential there is no single relationship which can be applied to all the alloys.

In addition to chemical milling of components to substitute the conventional milling, the method can also be used as an aid in the detection of cracks and other surface defects.

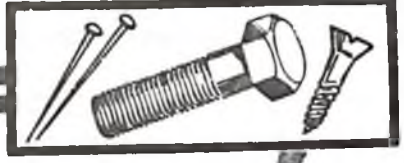
REFERENCES

1. International Metallurgical Reviews Vol. 20, 1975, Review 194, "Chemical Milling" by J. W. Dini, Sandia Laboratories, published by The Metals Society and the American Society for Metals.

2. Principles of Magnesium Technology by E. F. Emley. Pergamon Press (1966).

ELECTROPLATERS & ANODISERS







ELECTROPLATING :-

Chrome, Nickel, Silver, Bronze, Brass, Tin, Zinc, Copper, Cadmium, Chromate Processing, Barrel plating etc.

Auto Motor Bumpers & Guards a speciality. Remember, it is the quality that counts! Work carried out to I.S., B.S. & ASTM Specifications.

ALUMINIUM ANODISING :-

Specialists in Industrial & Structural Anodising.

KOHINOOR ELECTRO GILDERS

(Estd. 1932)

Khetwadi 10th Lane. Bombay-4. Phone : 351786